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Guide to Common Natural Enemies of the Nantucket Pine Tip Moth

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On the Cover

Eurytoma pini is one of the most abundant tip moth parasitoids in North America. On the half page, photo shows the damage of Nantucket pine tip moth.

Additional Copies

For additional copies of this publication, please contact John Nowak in Athens, Georgia at (706) 542-2264 (email: jnowak@bugs.ent.uga.edu) or Richard Reardon at (304) 285-1566 (email: rreardon@fs.fed.us).

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Contents

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Introduction

The Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Lepidoptera: Tortricidae), is a native pest of young pine plantations in the southern U.S. and is becoming more important because of its potential to reduce economic gains associated with the use of intensive forest management practices (Nowak and Berisford 2000).

Larvae of the Nantucket pine tip moth (Fig. 1a) reduce tree growth by mining tree buds and shoots. This insect has 2-5 generations per year and the pupal stage (Fig. 1b) can be found inside the shoots, where it overwinters.

Natural enemies are considered to be important regulators of tip moth populations, causing greater than 50% mortality (Gargiullo and Berisford 1983), and recent research projects have dealt with their conservation (McCravy and Berisford, *in press*; McCravy and others, 2001).

Two parasitoid species have also been successfully introduced into epidemic tip moth populations (Swenk 1927, Wadley 1932,

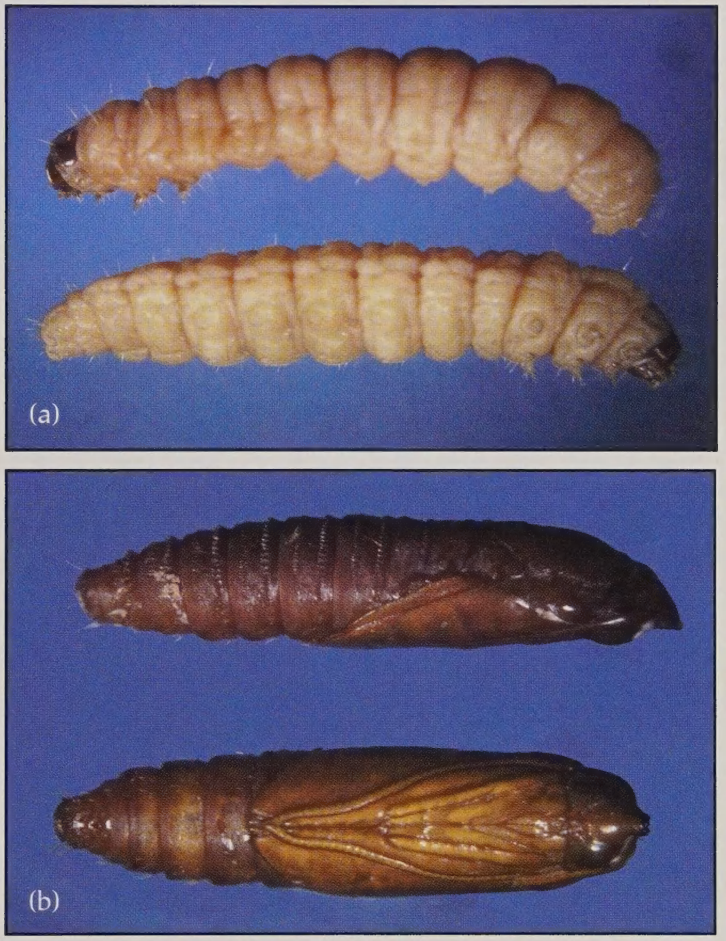

Fig. 1a-b. (a) The larvae of the Nantucket pine tip moth reduce tree growth by mining tree buds and shoots, while (b) the pupae can be found inside the shoots, where the pupae overwinter.

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Scriven and Luck 1978), and there has been a successful release of an egg parasitoid (Orr and others 2000). However, many questions remain about the most effective means to conserve natural enemies and their impact on tip moth populations. Therefore, there is a need for more research on tip moth natural enemies, but there is no extensive reference collection available for help with their identification.

This guide is intended to help people recognize the more common and important natural enemies of the Nantucket pine tip moth. It is not intended to be a comprehensive review of all natural enemies associated with tip moth or a complete taxonomic key.

Yates' (1967) key to parasitoid species provides a more complete review of taxonomic characters. The species (or species groups) included in this guide have been identified in most surveys of tip moth natural enemies and account for 75%, 92%, 91%, and 95% of the tip moth parasitism reported in the four most extensive studies conducted (Eikenbary and Fox 1965, Freeman and Berisford 1979, Lashomb and others 1980, and McCravy and Berisford 2000, respectively). In order to effectively use this guide, some basic entomological training is assumed although a glossary of terms is provided.

Insect orders and families are arranged in phylogenetic order, according to Borror and others (1989). All references to tip moth refer to *R. frustrana* and not to any of its congeneric species (unless otherwise indicated). References to parasitoids of larval tip moth indicate parasitoids of larval tip moth that complete development in the larval stage, and parasitoids of pupal tip moth refer to parasitoids that complete development in the pupal stage.

COLEOPTERA

Cleridae

Clerids, also known as checkered beetles, have elongate bodies (length usually < 12 mm) that are densely covered with bristly hairs (Fig. 2a). The head is usually as wide or wider than the pronotum. The pronotum is narrower than the elytra and often cylindrical. Most are predaceous as larvae and adults, and many are important predators of wood-boring beetles.

Phyllobaenus spp.

Phyllobaenus spp. are the most common insect predators of tip moth. Both larval and adult stages are predaceous, and appear most important in regulating first generation tip moth larvae and pupae densities.[1]

Phyllobaenus spp. larvae (Fig. 2b) are red to purple in color, have strongly prognathous mouthparts, and have distinct urogomphi. Thirty-two percent of infested pine shoots contained *Phyllobaenus* spp. larvae in a survey conducted in the piedmont of South Carolina (Eikenbary and Fox 1968).

Body Length: 8-10 mm
Natural Range: Poorly defined; at least the southeastern USA

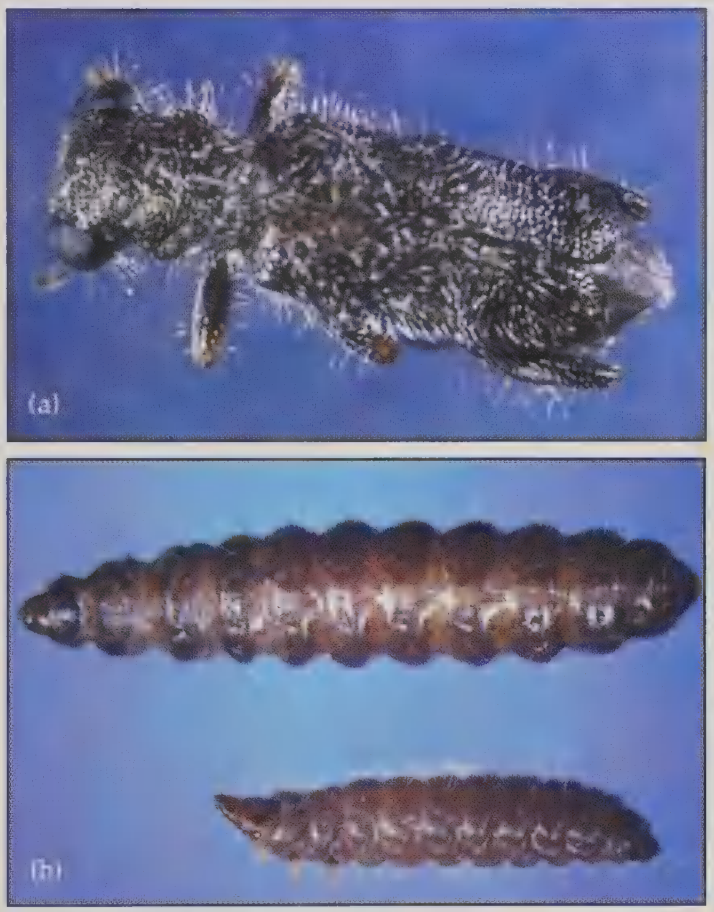

Fig. 2a-b. Clerids, or checkered beetles, have long bodies covered with bristly hairs. *Phyllobaenus* spp. are the most common insect predators of tip moth. Shown are: (a) an adult, and (b) larvae of *Phyllobaenus* spp.

[1] *Phyllobaenus* sp. adults are dark in color.

DIPTERA

Tachinidae

Tachinids are robust flies (Fig. 3a), usually < 14 mm in length. They have a well-developed post-scutellum, and their arista are usually bare. The wings have the first posterior cell narrowed or closed distally. Tachinid larvae are parasitic, and many are important natural enemies of pest species.

Lixophaga mediocris Aldrich

Lixophaga mediocris (Fig. 3b) completes development within tip moth larvae and pupates externally inside the shoot. It is the only fly species that is a well-known tip moth parasitoid (Eikenbary and Fox 1965, Freeman and Berisford 1979, Lashomb and others 1980, and McCravy and Berisford 2000).

Emergence patterns coincide with tip moth emergence. This species is the most common tip moth parasitoid in the piedmont and coastal plain of Georgia, and accounted for 36% and 45% of total parasitoids reared in two studies (Freeman and Berisford 1979, McCravy and Berisford 2000, respectively).

In South Carolina, *L. mediocris* is the second most common parasitoid found throughout the state (Eikenbary and Fox 1965), and appears to increase in importance in the coastal plain. *Lixophaga mediocris* was also consistently recovered from heavy

Fig. 3a-b. Tachinids are robust flies: (a) an adult, and (b) a larva (left) and pupa (right) of *Lixophaga mediocris*. *Lixophaga mediocris* is the only fly species that is a well-known tip moth parasitoid.

tip moth infestations throughout Missouri (Kearby and Taylor 1975). Lewis and others (1970) failed to rear *L. mediocris* from collections made in the mountains of Virginia, but the species is known to occur there. Inoculative releases of *L. mediocris* were unsuccessful in controlling western pine tip moth, *R. bushnelli* Miller, infestations in Nebraska (Dowden 1962).

Body Length: 3-3.8 mm
Natural Range: Throughout the native range of tip moth

HYMENOPTERA

ICHNEUMONOIDEA

Wasps in this superfamily vary considerably in body length (2-40 mm). Most species have normal wing venation, long, threadlike antennae with ≤16 segments, and a pronotum triangular in profile.

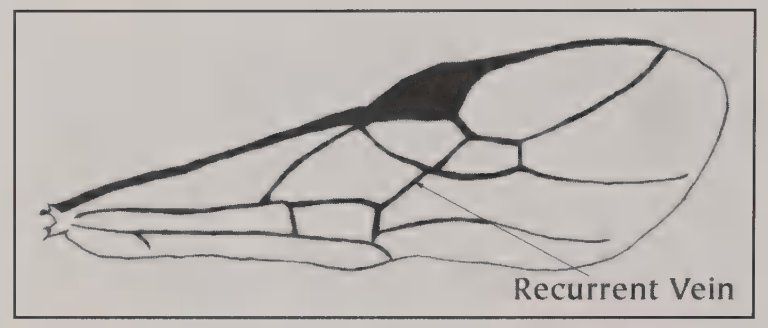

Fig. 4. Forewings of braconids have one recurrent vein (or none).

Braconidae

Braconids are generally ≤15 mm in length, and brownish or black. Forewings have one recurrent vein or none (Fig. 4). This is a large family with very diverse parasitic habits.

Agathis acrobasidis (Cushman)

Agathis acrobasidis is a larval tip moth parasitoid (Fig. 5). This species accounted for <3% of total parasitoids reared in three studies (Eikenbary and Fox 1965, Freeman and Berisford 1979, McCravy and Berisford 2000).

Body Length: 6 mm
Ovipositor Length: 4 mm
Natural Range: Poorly defined; at least Ohio south to Florida and west to Colorado; likely throughout the native range of tip moth

Fig. 5. *Agathis acrobasidis* is a larval tip moth parasitoid.

Bracon sp.

Several *Bracon* spp. are larval tip moth parasitoids (Fig. 6). These species are consistently found in tip moth parasitoid studies, but they do not account for a significant portion of total parasitism (Eikenbary and Fox 1965, Freeman and Berisford 1979, McCravy and Berisford 2000).

Body Length: Variable; usually < 4 mm
Natural Range: Throughout the range of tip moth

Fig. 6. *Bracon* sp. is a larval tip moth parasitoid consistently found in tip moth parasitoid studies.

Macrocentrus ancylivorus Rohwer

Macrocentrus ancylivorus is a larval tip moth parasitoid (Fig. 7). McCravy and Berisford (2000) report that *M. ancylivorus* accounted for 6% of total parasitoids reared from collections in the coastal plain of Georgia. Eikenbary and Fox (1965) and Freeman and Berisford (1979) found few *M. ancylivorus* in collections made throughout South Carolina and in the piedmont of Georgia.

Body Length: 3.5–4.5 mm
Ovipositor Length: 5.5 mm
Natural Range: Throughout the range of tip moth

Fig. 7. *Macrocentrus ancylivorus* Rohwer is a larval tip moth parasitoid.

Ichneumonidae

Ichneumonids are generally < 40 mm in length. Forewings have two recurrent veins (Fig. 8). This is one of the most speciose families of insects, with great variation in size, color, and parasitic habits.

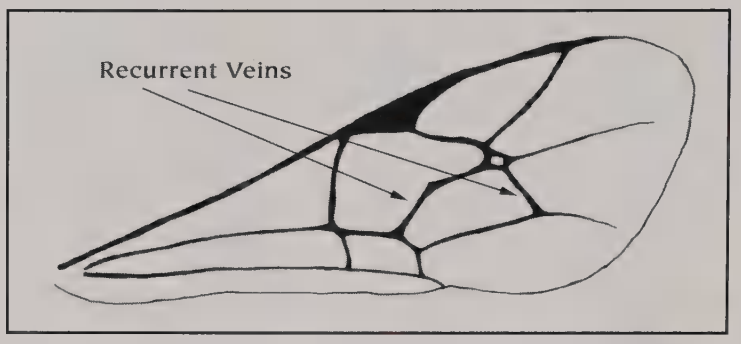

Fig. 8. Ichneumonids have forewings with two recurrent veins.

Campoplex frustranae Cushman

Campoplex frustranae is a pupal tip moth parasitoid (Fig. 9). Emergence patterns coincide with that of tip moth. This species accounted for 24% of total parasitoids reared in the piedmont of Georgia (Freeman and Berisford 1979), and it is the second most common parasitoid species in that region. Eikenbary and Fox (1965) reported that *C. frustranae* accounted for 47% of parasitoids reared from piedmont collections, but only 18% reared from coastal plain collections.

Fig. 9. *Campoplex frustranae* is a pupal tip moth parasitoid.

Campoplex frustranae was absent from parasitoid studies in Florida (McGraw and others 1974) and the coastal plain of Georgia over four consective generations (McCravy and Berisford 2000). However, it was the second most common species in a study in Maryland (Lashomb and others 1980). It is clear that this species is more common in the piedmont.

Campoplex frustranae has been successfully introduced for control of tip moth infestations. An inoculative release occurred in Nebraska in 1924 for control of *R. bushnelli* (Dowden 1962). More recently, parasitoids collected from Georgia and Arkansas were released in California to control tip moth infestations in Monterey pine (*Pinus radiata* D. Don) (Scriven and Luck 1978).

Body Length: 5 mm
Antennal length: 3 mm
Ovipositor Length: 1.5 mm
Natural Range: Likely throughout the range of tip moth, but perhaps not in extreme portions of the southeastern USA

Itoplectis conquisitor (Say)

Itoplectis conquisitor is usually a pupal tip moth parasitoid (Fig. 10). However, it has been documented that they are occasionally hyperparasitic on ichneumonid and braconid pupae (Townes and Townes 1960). This species accounted for < 2% of total parasitoids reared in three separate studies (Eikenbary and Fox 1965, Freeman and Berisford 1979, and McCravy and Berisford 2000). *Itoplectis conquisitor* was released in Nebraska for controlling *R. bushnelli*, and establishment was confirmed (Dowden 1962).

Front Wing Length: 3.5-12.5 mm
Natural Range: Throughout the range of tip moth

Fig. 10. *Itoplectis conquisitor*, a pupal tip moth parasitoid, is occasionally hyperparasitic on ichneumonid and braconid pupae.

Temelucha sp.

Temelucha sp. is a larval tip moth parasitoid (Fig. 11). This species accounted for < 1% of total parasitoids reared in three separate studies (Eikenbary and Fox 1965, Freeman and Berisford 1979, McCravy and Berisford 2000).

Body Length: 5-8 mm
Natural Range: Poorly defined; likely throughout the range of tip moth

Fig. 11. *Temelucha* sp. is a larval tip moth parasitoid.

CHALCIDOIDEA

Wasps in this superfamily are generally minute to small ($\leq$6 mm in length) with greatly reduced wing venation (Fig. 12) and elbowed antennae having $\leq$13 segments. The pronotum is generally squarish or rectangular in lateral view.

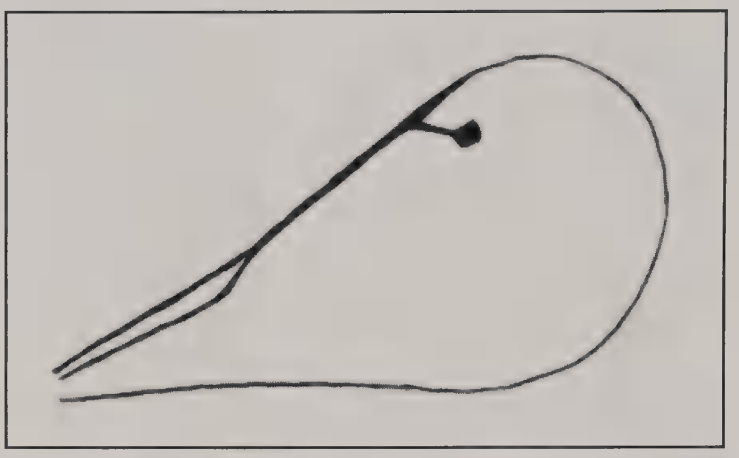

Fig. 12. Reduced wing venation representative of Chalcidoidea.

Trichogrammatidae

Trichogrammatids are minute wasps (<0.7 mm in length) and robust in build. Unlike other chalcidoid wasps, they have 3-segmented tarsi. Wing setae are often arranged in rows.

Trichogrammatids are strictly egg parasitoids, and many are important as biological control agents.

Trichogramma spp.

Trichogramma spp. are minute egg parasitoids which are important in regulating tip moth populations. Eggs parasitized by *Trichogramma* spp. have a distinctly blackened appearance (Fig. 13).

Fig. 13. Eggs of the pitch pine tip moth, *Rhyacionia rigidana* (Fernald), parasitized by *Trichogramma* sp. (*R. frustrana* eggs laid singly). Parasitized eggs have a distinctly blackened appearance.

Some studies have reported >65% of eggs being parasitized (Yates 1966). Gargiullo and Berisford (1983) documented that parasitism is generally lower in the spring (12%) than the summer generation (47%). Other authors (McCravy and Berisford 1998) have demonstrated similar results.

In one study egg parasitism was demonstrated to be density-dependent (Gargiullo and Berisford 1983); however, in another study a density independent relationship was found (McCravy and Berisford 1998). Experimental inundative releases of *Trichogramma exiguum* Pinto and Platner suppressed tip moth infestations in a study conducted in North Carolina (Orr and others 2000).

Body Length: <0.7 mm
Natural Range: Throughout the range of tip moth

Eulophidae

Eulophids are generally small wasps (< 3 mm in length) with four tarsal segments, a short, straight protibial spur, and $\leq$ 10 antennal segments. Many are parasitoids of hosts concealed in plant tissues.

Fig. 14. *Hyssopus rhyacioniae* is a highly gregarious parasitoid of larval tip moth.

Hyssopus rhyacioniae Gahan

Hyssopus rhyacioniae is a highly gregarious, parasitoid of larval tip moth (Fig. 14). McCravy and Berisford (2000) found this species to be the third most common parasitoid in the coastal plain of Georgia, but it was absent from collections in the piedmont (Freeman and Berisford 1979). Eikenbary and Fox (1965) showed the species was more abundant in the coastal plain than the piedmont of South Carolina. Inoculative releases of *Hy. rhyacioniae* were unsuccessful in controlling *R. bushnelli* infestations in Nebraska (Dowden 1962).

Body Length: 1.3 mm
Natural Range: Poorly defined; at least portions of Georgia, Nebraska, South Carolina, and Virginia; a similar species (*Hyssopus thymus* Girault) is reported to have a much wider distribution

Eupelmidae

Eupelmids are generally small (< 2 mm in length), and unlike most other chalcidoids, have a convex mesopleuron with no groove for reception of the hind femur. The mesonotum is often relatively flat. The midtibial spur is usually very stout and prominent. Many are proficient jumpers. The body often assumes a U-shape in death. Many are parasitoids of insects concealed in plant tissues.

Eupelmus cyaniceps Ashmead

Eupelmus cyaniceps is generally a gregarious parasitoid of larval and pupal tip moth (Fig. 15), but has also been reported to be hyperparasitic (Harman and Kulman 1973). Most studies report this species as representing < 5% of total parasitoids (Freeman and Bersiford 1979, McCravy and Berisford 2000).

Body Length: 3.6 mm
Natural Range: Throughout the native range of tip moth

Fig. 15. *Eupelmus cyaniceps* is generally a gregarious parasitoid of larval tip moth.

Perilampidae

Perilampids are short, compact wasps (6-8 mm in length), often metallic blue or green in coloration. They may superficially resemble chrysidids. The pronotum is short and strap-like, and the abdomen is often relatively small and triangular in side view. The thorax is often pitted. Many are hyperparasitic on primary parasitoids of Lepidoptera.

Fig. 16. *Perilampus fulvicornis* is a parasitoid of larval and pupal tip moth and a hyperparasitoid of *C. frustranae* and perhaps also of *E. pini*.

Perilampus fulvicornis Ashmead

Perilampus fulvicornis is a parasitoid of larval and pupal tip moth and a hyperparasitoid of *C. frustranae* and perhaps *E. pini* (Fig. 16). This species is fairly common in the piedmont of Georgia (Freeman and Berisford 1979), less common in South Carolina (Eikenbary and Fox 1965), and absent from surveys conducted in the coastal plain of Georgia (McCravy and Berisford 2000). However, *P. fulvicornis* is present in Florida (Yates 1967).

Body Length: < 2.0 mm
Natural Range: Likely throughout the range of tip moth

Eurytomidae

Eurytomids are generally black or yellow. The best distinguishing characteristic is the large, rectangular pronotum in lateral view. The head and mesosoma are often covered with reticulations or pits. The family includes a wide range of feeding habits, including parasitism, predation, and plant feeding.

Eurytoma pini Bugbee

Eurytoma pini is one of the most abundant tip moth parasitoids (Fig. 17a-b) in North America (Warren 1985). This species is generally considered hyperparasitic or cleptoparasitic (Arthur 1961, McCravy and Berisford 2000), although some authors have considered this species to be a primary parasitoid (Cushman 1927). McCravy and Berisford (2000) suggested that *E. pini* might have detrimental effects on *L. mediocris*

Fig. 17a-b. *Eurytoma pini* is one of the most abundant tip moth parasitoids in North America. Shown are: (a) female and (b) male.

populations. *Eurytoma pini* was the second most common parasitoid collected in the coastal plain of Georgia where it accounted for 25% of all parasitoids (McCravy and Berisford 2000). The species is apparently less common in the piedmont (Eikenbary and Fox 1965, Freeman and Berisford 1979). However, it was the third most common species reared in a study in Maryland (Lashomb and others 1980). Inoculative releases of *E. pini* in Nebraska were unsuccessful (Dowden 1962).

Body Length: 3-4.5 mm
Natural range: Throughout the native range of tip moth

Chalcididae

Chalcidids are robust wasps (< 27 mm in length) with distinctly enlarged hind femora and arched tibiae. They often have black and/or yellow coloration. Most are parasitoids of Lepidoptera.

Conura side (= *Spilochalcis flavopicta* (Cresson)) Walker

Conura side (Fig. 18) is largely hyperparasitic on *L. mediocris*. This species accounts for < 2% of total parasitoids reared in two separate studies (Freeman and Berisford 1979, McCravy and Berisford 2000).

Body Length: 3.5 mm
Natural Range: Throughout the native range of tip moth

Fig. 18. *Conura side* is largely hyperparasitic on *L. mediocris*.

Haltichella rhyacioniae Gahan

Haltichella rhyacioniae is a pupal tip moth parasitoid (Fig. 20), although one specimen has been found to be hyperparasitic on *L. mediocris* (Freeman and Berisford 1979).

Haltichella rhyacioniae is generally 3-4 times more abundant than *C. side*, although both are considered to be of minor importance (Eikenbary and Fox 1965, Freeman and Berisford 1979, McCravy and Berisford 2000). Inoculative releases of *Ha. rhyacioniae* were unsuccessful in controlling *R. bushnelli* in Nebraska (Dowden 1962).

Body Length: 2.8-3.6 mm
Natural Range: Likely throughout the native range of tip moth

Fig. 19. *Haltichella rhyacioniae* is a pupal tip moth parasitoid.

CHRYSIDOIDEA

BETHYLIDAE

Members of this genus are generally small (1-3 mm in length) with an elongate and rectangular head (dorsal view) and prognathus mouthparts. Antennae have < 14 segments and are not elbowed. Forewings have a closed median cell, and venation is reduced, but differs from that of chalcidoids in having a parastigma in addition to the stigma (Fig. 20).

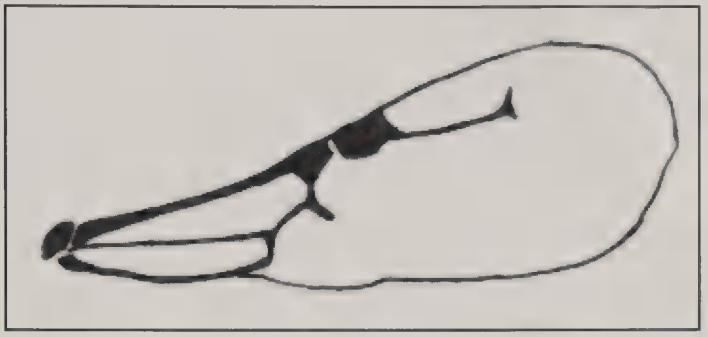

Fig. 20. Forewings of *Goniozus* spp. have a closed median cell and reduced venation.

Goniozus sp.

Goniozus spp. are larval tip moth parasitoids (Fig. 21). This species is generally uncommon accounting for < 2% of total parasitoids reared in three separate studies (Eikenbary and Fox 1965, Freeman and Berisford 1979, McCravy and Berisford 2000).

Body Length: 2.3 mm
Natural Range: Poorly defined; at least the southeastern USA, but likely throughout the native range of tip moth

Fig. 21. Members of the genus *Goniozus* are generally small with an elongate and rectangular head and prognathus mouthparts.

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Key to Adults of Parasitoids of the Nantucket Pine Tip Moth

1.One pair of wings ..... Diptera; *Lixophaga mediocris*

1'. Two pairs of wings .....2 (Hymenoptera)

2. Antennae with 16 or more segments; well-developed venation in front wings; stigma well-defined (Figs. 4 and 8) ..... 3 (Ichneumonoidea)

2'. Antennae with 14 or less segments; venation very reduced; stigma highly reduced or lost (Fig. 12) 8

3. Front wings with 1 recurrent vein (Fig. 4) ..... 4 (Braconidae)

3'. Front wings with 2 recurrent veins (Fig.8) ..... 6 (Ichneumonidae)

4. Wings smoky colored or opaque ..... *Agathis acrobasidis*

4'. Wings clear, not as above 5

5. Antennae and ovipositor shorter than body ..... *Bracon* sp.

5'. Antennae and ovipositor as long or longer than body ..... *Macrocentrus ancylivorous*

6. First abdominal segment sessile; legs banded... ... .*Itoplectis conquisitor*

6'. First abdominal segment petiolate; legs unicolored 7

7. Face with thick pubescence; clypeus not distinctly separated from face by a groove; eye not surrounded by light ring ..... *Campoplex frustranae*

7'. Face without thick pubescence; eyes circled by a light ring..... *Temelucha rhyacioniae*

8. Front wings with closed median cell; antennae not elbowed; front wings with parastigma (Fig. 21) ..... Bethyloidea (*Goniozus* sp.)

8'.Wing venation greatly reduced, no closed cells in front wing (Fig. 12); antennae elbowed ..... 9 (Chalcidoidea)

9. Tarsi 3-segmented; wing pubescence arranged in rows; extremely minute insect ..... Trichogrammatidae (*Trichogramma* sp.)*

9'. Tarsi 4- or 5-segmented; wing pubescence not in rows; size variable 10

10. Tarsi 4-segmented; apical spur on front tibia small and straight ..... Eulophidae (*Hyssopus rhyacionae*)

10'. Tarsi 5-segmented; apical spur on front tibia large and curved 11

11. Mesopleura large and convex, usually without a femoral groove; apical spur of middle tibia very large and stout; body green in color ..... Eupelmidae (*Eupelmus cyaniceps*)

11'. Mesopleura with a groove for the reception of the femora; apical spur of middle tibia normal, not enlarged; body not green 12

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* Adults not included in handbook; only *Trichogramma* spp. parasitized tip moth egg (Fig. 13).

12. Hind femora robustly enlarged, and toothed beneath; hind tibia arched..... 13 (Chalcididae)

12'. Hind femora not enlarged; either not toothed or with only 1 or 2 teeth; hind tibia not arched 14

13. Body shiny black ..... *Haltichella rhyacioniae*

13'. Body tan and cream colored; hind femora distinctly enlarged ..... *Conura side*

14. Pronotum short, wider than long; abdomen transversely convex, thorax very robust; metallic ..... Perilampidae (*Perilampus fulvicornis*)

14'. Pronotum more or less quadrate, about as long as wide; abdomen of female rounded or ovate, more or less compressed; thorax of more normal proportions, coarsely punctate, not metallic ..... Eurytomidae (*Eurytoma pini*)

Glossary

cleptoparasitism	Parasitic relation in which a female seeks out prey or stored food of another female, usually belonging to a different species, and appropriates it for the rearing of her own offspring.
elytron	Leathery forewing of beetles.
mesopleuron	Lateral region of the second or middle thoracic segment.
mesosoma	In higher Hymenoptera, the middle tagma of the body, composed of the three thoracic segments and the first true abdominal segment.
parastigma	Dilation at the junction of the submarginal and marginal veins.
prognathus	Having the head horizontal with the jaws directed forward.
pronotum	Upper and dorsal part of the prothorax.
recurrent veins	In adult Hymenoptera, traverse veins immediately posterior to the cubital vein.
stigma	A dense, often discolored part of the costal margin of the wing, usually at the apex.
urogomphi	In larval Coleoptera, usually paired processes from the posterior end of the tergum of the ninth abdominal segment.

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